"On the Condition in which Fats are absorbed from the Intestine." By B. Moore and D. P. Rockwood. Communicated by Professor E. A. Schäfer, F.R.S.

Received December 24, 1896,—Read February 4, 1897.

(From the Physiological Laboratory of University College, London.)

In 1858 Dr. W. Marcet* announced to this Society the discovery that bile possesses the remarkable property of dissolving to a clear solution large amounts of fatty acids, and mixtures of these, when heated above their melting points, and that, on cooling, these bodies are again thrown out as a fine precipitate or emulsion.

We have repeated these experiments, and are able to confirm the accuracy of Marcet's observation. Thus we found that 6 c.c. of dog's bile at 62° C. dissolved completely 1·5 grams of the mixed fatty acids† of beef suet, and similar solubilities were found in other cases.

No other observations than these have, so far as we are aware, been made on the effect of temperature on the solubility of fatty acids in bile; although different writers have mentioned that fatty acids are soluble in bile, no measurements have been made of the extent of their solubility. Altmann‡ has recently surmised that fats are absorbed from the intestine as fatty acids, dissolved in the intestine by the agency of the bile, but has made no quantitative experiments on the solubilities of the fatty acids in bile. The forgotten experiments of Marcet, mentioned above, led us to think that the fatty acids might possess, *at the temperature of the body*, a fair amount of solubility in bile, and as the solubility at this temperature is that of most physiological interest, we have made a series of determinations of the solubilities of oleic, palmitic, and stearic acids, and of natural mixtures of these in the proportions in which they occur in lard, beef suet, and mutton suet, in the bile of the ox, pig, and dog.

Different methods were used in the determination of these solubilities:—

1. To a measured amount of the bile under experiment, kept at a temperature of 39° C., small weighed quantities of the fatty acid under experiment were added, until no more dissolved.

2. A quantity of bile was saturated at 39° C., with excess of the fatty acid, and filtered from the excess of undissolved acid through a

* 'Roy. Soc. Proc.,' 1858, vol. 9, p. 306.

† Throughout this communication the expression "fatty acids" means the fatty acids present in fats, oleic, palmitic, and stearic acids.

‡ 'Arch. f. Anat. u. Physiol.,' 1889, Anat.-Abth., Suppl. Band, p. 86.

The Royal Society is collaborating with JSTOR to digitize, preserve, and extend access to *Proceedings of the Royal Society of London.* www.jstor.org

hot funnel, at this temperature; the filtrate was cooled to about 0° C., and the precipitate collected, dissolved in ether, recovered therefrom, and weighed; the weight, compared with the volume of the filtrate, gave a measure of the solubility.

3. To a series of equal volumes (10 c.c.) of bile in test-tubes, a rising series of weights of fatty acids was added (0·05, 0·1, 0·15, 0·2, &c., grams), and those tubes noted, in which, after the lapse of a sufficient time at 39° C., complete solution did not take place.

The following is a summary of our results.

	Lard fatty acids.*	Beef suet acids.	Mutton suet acids.	Oleic acid.	Palmitic and stearic acids.
1. Ox bile	2·5—4 p. c.	2·5—3 p. c.	1—2·5 p. c	4—5 p. c.	Less than 0·5 p. c.
2. Pig's bile ..	4 „	5—6 „	1—2·5 „	—	—
3. Dog's bile ..	6·25 „	4—7 „	2 „	—	—

The fatty acids are not dissolved as soaps, but probably as fatty acids, for the solution becomes strongly acid; moreover, the material thrown out on cooling dissolves easily in ether, and, when recovered, saponifies at once with sodium carbonate. The solution is not entirely due to the bile salts, for mere removal of the "bile mucin" greatly diminishes the solvent power, although the "mucin" redissolved in sodium carbonate solution has no solvent power, and, again, a solution of mixed bile salts† stronger than bile has not nearly so much solvent power as the bile itself.

Palmitic and stearic acids are very feebly soluble in bile at 39° C., and in mixtures are probably dissolved by the aid of the admixed oleic acid.

Action of Filtered Intestinal Contents on Fats.

The filtered intestinal contents contain both pancreatic juice and bile, and hence should both decompose and dissolve fats at body temperature if these are absorbed as *dissolved* fatty acids; this was experimentally found to be the case with filtered intestinal contents of the dog, which in different cases possessed a very variable

* The numbers given are the minimum and maximum of a number of determinations in different samples of bile.

† The solution used was a 9 per cent. solution of the bile salts of a sample of ox bile which dissolved 2·5 per cent. of the fatty acids of beef suet; this solution of bile salts only dissolved 1 per cent.

power, dissolving 1 to 5 per cent. of the fat of beef suet at 39° C. The solution becomes viscid, semi-fluid, or completely solid on cooling, and redissolves on warming again. With the filtered contents of the intestine of the pig and rabbit similar results were *not* obtained, but the fat became altered, being in part converted into fatty acids, and in part giving rise to a voluminous precipitate.

Simultaneous Action of Pancreas and Bile on Fats.

Finely minced, fresh dog's pancreas (1 gram) was added to bile (10 c.c.), and then the fat of beef suet (0·25 gram); the fat completely dissolved in three hours at 40° C.; on cooling, the solution became turbid, and finally semi-solid. In a control experiment, pancreas alone decomposed fat into fatty acids, but did not dissolve it.

The solubilities stated above are quite sufficient to account for the removal of all the fat of the food from the intestine as dissolved fatty acid, since they exceed the concentrations found in the intestine of other materials, such as sugars and albumoses, which are removed in solution. Other experiments, however, on the reaction of the intestine during fat absorption, lead us to think that all the fat is not removed as dissolved fatty acids, but that these are replaced to a variable extent (*in some animals, to a very large extent or completely*) by dissolved soaps.

Reaction of Intestinal Contents during Fat Absorption.

We have determined the reaction of the contents of the dog's small intestine during fat absorption, from pylorus to cæcum, to various indicators, litmus, methyl-orange, and phenolphthaleïn, and cannot agree with the statement of some other experimenters, that it is acid throughout.* In sixteen experiments on this animal we only once found the reaction acid to litmus up to the cæcum, and this was an obviously poor experiment, in which the intestine was almost empty. The reaction to litmus at the pylorus is neutral, faintly acid, or faintly alkaline; from here onwards the acidity increases, reaches a maximum about the middle of the small intestine, and then becomes less acid, to change to alkaline at a point situate two-thirds to three-fourths of the way along the intestine; from this point on to the cæcum the alkalinity increases.† The reaction to methyl-orange and phenolphthaleïn explains this; the intestine is alkaline to methyl-orange all the way from pylorus to cæcum, and equally com-

* Cash, 'Arch. f. Anat. u. Physiol.,' 1881, p. 386; Munk, 'Zeitsch. f. Physiol. Chem.,' vol. 9, 1885, pp. 572, 574.

† There is usually a reversion to an acid reaction in the large intestine, in which case the contents of the cæcum are almost neutral.

pletely acid to phenolphthaleïn, showing that *the acid reaction to litmus in the upper part is due to weak organic acids*, while the alkaline reaction in the lower is due to fixed alkali, accompanied by dissolved carbonic acid. The alkaline reaction to methyl-orange in the upper part, where it is acid to litmus and phenolphthaleïn, shows that in that part there is an excess of bases, above that quantity necessary to combine with all the inorganic acids, which are combined with very weak organic acids (probably fatty acids), for methyl-orange is a stable indicator, and does not react to such acids, while litmus, and, still more so, phenolphthaleïn, are indicators which are affected by these acids. In the lower third or thereabouts, where the reaction is alkaline to litmus, there cannot be any fatty acids present in solution.

Any fat absorbed as free fatty acid in solution must, therefore, be taken up from the upper two-thirds or three-fourths of the intestine where the reaction is acid to litmus, but even here a considerable part is probably being absorbed in solution as soaps, as is shown by the reaction being at the same time alkaline to methyl-orange. In the lower part all the fat absorbed must be taken up as soaps.

During fat absorption in the white rat,* the reaction of the contents of the small intestine is commonly alkaline to litmus from pylorus to cæcum, and is never acid for a greater distance than 2 or 3 in. below the pylorus; in this animal, therefore, nearly all the fat must be absorbed in solution as soaps.

We have not investigated the reaction of the intestinal contents in other animals during fat absorption, but in the rabbit, during carbohydrate absorption, it is strongly alkaline all the way, from pylorus to cæcum, and in the pig the mixed contents during the absorption of a mixed meal (meal and oats) had a strong alkaline reaction. As already stated, the filtered contents in these animals do not perfectly dissolve fat, and the portion dissolved must be in the form of soap, because the reaction remains alkaline to litmus after solution. In such animals it is probable that the greater part of the fat must be absorbed as soaps.

The main objections which have been urged against absorption of fats as soaps are, first, absorption in presence of an acid reaction in the dog, in which case it was supposed impossible that soaps could be present simultaneously in solution,† and, secondly, that the

* In this animal the intestinal contents are usually semi-solid. Care was taken to mix them so as not to obtain the alkaline surface reaction sometimes described. On thorough mixing an alkaline reaction was obtained.

† The acid reaction is also commonly supposed to preclude the possibility of the formation of an emulsion, and Cash ('Arch. f. Anat. u. Physiol.,' 1881, p. 386), in experiments chiefly made to determine this point, failed to find any emulsion within the dog's intestine. In ten out of sixteen experiments we obtained more or less emulsion, and in five of these, in almost the entire length, a perfect emulsion, containing immense numbers of minutest fat globules, *and possessing a marked acid*

amount of alkali required in the intestine for the absorption of all the fats of a fatty meal, as soaps, is out of all proportion to the amount actually present, being about twice the total alkalinity of the body.* The first objection has already been discussed; it has been shown that the acid reaction is due to weak organic acids, and that an alkaline reaction can be obtained by the use of a proper indicator, due to a compound of these weak acids with bases; in other words, to soaps.

The second objection may be met by the supposition that the same quantity of alkali acts cyclically as a carrier in conveying quantity after quantity of fatty radicle, as soap, from the intestine. The soaps are, it is known, broken up in the intestinal cells, and formed into fats by the action of the cell; in such a reaction alkali is set free, and there is no obvious reason why it should not be returned to the intestine and serve to carry a fresh portion of fatty radicle dissolved as soap into the epithelial cells. Such an action takes place in the acid secreting cell of the gastric gland, where sodium chloride is taken up from the blood, split into acid and alkali, and the alkali returned to the blood while the acid passes into the gland lumen; it is not, therefore, unreasonable to suppose that a similar action can take place in the intestinal absorbing cell.

We conclude that in certain animals, such as the dog, fats are absorbed partially as dissolved fatty acids, and partially as dissolved soaps; while in other animals, such as the white rat, fats are chiefly, if not entirely, absorbed as dissolved soaps.

"The Gaseous Constituents of certain Mineral Substances and Natural Waters." By William Ramsay, F.R.S., and Morris W. Travers, B.Sc. Received December 30, 1896,—Read February 4, 1897.

It is still uncertain whether helium is a single elementary gas or a mixture of two or more gases. If a mixture, it is probable that they should occur independently, and that the proportion of the constituent gases should vary in samples from different sources. During the past year the gases obtained from a large number of minerals and natural waters have been examined with a view to investigate this point, and, also, to determine whether any new gaseous element could be discovered. In every instance the results have been negative; no

reaction to litmus. Although fats are not absorbed in the form of an emulsion, it is evident that the formation of an emulsion in the intestine must enormously increase the surface exposed to the action of the intestinal fluids, and proportionately increase the rate at which the fats are decomposed and dissolved.

* Munk, 'Virchow's Archiv,' vol. 95, 1884, p. 408.